FIELD MONITORING OF BRIDGE SCOUR IN GEORGIA

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Abstract. Scour or erosion of the streambed near the foundations of a bridge is often referred to as "bridge scour." Bridge scour is caused by the interaction between turbulent flows induced by bridge structures and the streambed. These turbulent flows erode the streambed and cause scour holes. The Georgia Institute of Technology and the U.S. Geological Survey (USGS), in cooperation with the Georgia Department of Transportation and the Federal Highway Administration (FHWA), are conducting an investigation to improve bridge scour predictions by combining field monitoring, physical modeling in the laboratory, and three-dimensional numerical modeling of bridge scour. By integrating three-dimensional numerical modeling with laboratory and field measurements, it is proposed that some of the uncertainties associated with bridge scour predictions would be significantly reduced.

INTRODUCTION

Scour of the streambed at bridge piers and abutments is the leading cause of bridge failures in recent history. Bridge scour is the measure of the decrease in the channel bed elevation due to the interaction of turbulent flows induced by a bridge structure and the streambed. The turbulent flows erode the streambed and cause scour holes. Bridge scour is a function of flow energy, sediment-transport capacity, and bridge characteristics. Complexities associated with bridge scour have hampered satisfactory analyses and prediction procedures.

A bridge scour research project that integrates three-dimensional numerical modeling with laboratory and field measurements is being conducted by the Georgia Institute of Technology and the USGS, in cooperation with the Georgia Department of Transportation and the FHWA. The integration of the three components is intended to improve bridge scour predictions using one-dimensional methods. Greater accuracy of bridge scour predictions may lead to increased confidence in bridge design; thus, increasing public safety of the citizens who use the bridges. Improved bridge scour predictions may also decrease unnecessary expenses for scour countermeasures, making the bridge design process more efficient.

This paper discusses the field monitoring and sampling component of the project. This component of the research project will provide detailed field measurements of bridge scour that can be used to calibrate and refine the scale effects of laboratory and numerical models, so that bridge scour prediction techniques may be improved.

FIXED-FIELD INSTRUMENTATION

Channel geometry is the most fundamental component of a bridge scour data set and requires concurrent measurements of streambed elevation and horizontal position. Echo sounders measure the distance between a transducer and the streambed by emitting an acoustic pulse and measuring the time required for the pulse to reflect off the streambed and return to the transducer. Digital recording echo sounders process the signal and provide a single digital value through a computer port. Downward looking fathometers will be deployed on the upstream and downstream side of bridge piers and abutments (if abutments project into the streamflow). Fathometers are typically installed about three feet above the maximum bed elevation. Installation of transducers close to the streambed reduces any problems with the fathometer beam intersecting the edge of a bridge pier or abutments and reduces the possibility of debris hitting and damaging the transducers. Cables will run from each fathometer transducer to the fathometer array-control box in the instrument shelter. Satellite telemetry will provide water-level data so that approaching floods may be monitored in order to determine when to deploy a mobile field measuring crew. Channel bed elevations at monitoring points will be recorded by a minimum of once every hour.

Field instrumentation will be installed at four bridge sites, which will be chosen to represent various sediment types in Georgia. Detailed fixed instrumentation will be installed at two sites. One site will be located in the Coastal Plain Province, and the second site will be located in the Piedmont Province. Less-detailed fixed instrumentation will be installed at the remaining two USGS gaging stations. The detailed sites will have the following equipment:

- stage sensor;
- cross-channel two-dimensional velocity sensor;
- fathometer array to record streambed elevation;
- raingage;
- data logger and controller for each device;
- solar panel and instrumentation shelter; and
- satellite telemetry.

The less-detailed sites will have the same equipment except for the velocity sensor.

Stream stage affects scour directly (limiting dimensions of vortices and flow fields) and indirectly (as a measure of velocity and sediment transport capacity). The stage sensor will be a submerged pressure transducer or an acoustic device. The stage sensor will be a high-accuracy (0.02 foot, 6 millimeter minimum accuracy), standard USGS application device. Stage will be recorded at 15-minute intervals.

Water velocity is a critical bridge scour parameter that is used to quantify the available scour energy. The cross-channel velocity sensor provides two-dimensional velocity for a series of points across the channel in the bridge-approach section. The sensor will be mounted at a fixed location and aimed across the channel. These devices are being used to develop index velocity-discharge relations at many sites where stage is not an adequate indicator of discharge. The velocity meter uses acoustic-Doppler technology and has its own system controller on site. Velocities will be recorded at 15-minute intervals.

MOBILE FIELD INSTRUMENTATION

A mobile scour data-collection system has four components: instruments to measure velocity and channel-geometry data; instruments to deploy equipment in the water; an instrument to measure the horizontal position of the data collected; and a data storage device. For this investigation, an acoustic Doppler current profiler (ADCP) will be deployed from a manned or remote control boat and used to measure three-dimensional velocity profiles. A recording digital fathometer will be used to measure channel depths. Horizontal position will be measured using a kinematic differential Global Positioning System (GPS). Some of the parameters collected with the mobile instrumentation include:

- detailed channel geometry at and near the bridge;
- approach-flow velocities over the study reach;
- water-surface slope during flood events;
- visual analysis and notes on the surface velocity direction, channel and overbank;
- roughness, and vegetation cover;
- approximate measurements of the extent and composition of debris;
- photographs of channel and bridge at flood and low-flow conditions;
- water temperature;
- bridge and pier geometry; and
- bed-sediment samples and soil boring logs from the bridge crossing.

All data will be recorded and used to interpret and extend the data collected by the fixed instrumentation, and for the mathematical modeling component of this investigation.

STREAMBED SEDIMENT SAMPLING

Bed-material characteristics are important determinants of streambed erodibility and bed-material transport conditions. Techniques for bed-material sampling in sand-bed streams are described in Edwards and Glysson (1988), and Ashmore and others (1988). The objective for any of the collection techniques is to ensure that a representative sample is collected. The BMH-53 or BMH-80 hand samplers are used to collect the samples in sand-bed streams that are wadable. A BM-54 is used to collect samples in sand-bed streams that are too deep to be waded. Procedures are not well defined for sampling cohesive bed-materials; but a BMH-53 or similar cylinder sampler may be used on wadable streams. The type of sampler used will always be noted with the bed-material data.

Sampling locations will be selected to ensure samples are representative of the bed material controlling the sediment-transport processes in the study reach. In streams with cohesive beds, Sediment in the zone of scour will be sampled. In sand channels with uniform bed-material characteristics, the sampling location is not difficult to determine; but in coarse-bed streams with riffles and pools, bed-material characteristics vary significantly and a representative sample is much more difficult to obtain. Noncohesive bed-material in a scour hole is often coarser than and atypical of bed material controlling the sediment-transport processes of the stream. Thus, samples collected directly from a scour hole should be avoided when determining representative bed-material characteristics for the channel reach.

Bed material samples will be collected from several locations both in the bridge approach and the bridge sections, including in local scour holes. Bed-material samples will be analyzed by the Georgia Institute of Technology laboratories for grain-size distribution and other properties related to bridge scour.

SUMMARY

The data-collection process for the field monitoring component of the bridge scour research project will be conducted using fixed and mobile instrumentation to measure velocity and scour depth and by sampling streambed sediment within the study reach. Field instrumentation will be installed at four bridge sites, which will be chosen to represent various sediment types in Georgia. Detailed fixed-scour instrumentation will be installed at two of the sites, whereas only limited instruments in combination with existing streamflow gaging stations and historical scour measurements will be employed at the other two sites. Mobile instrumentation will be deployed during scour events at the two detailed study sites and will include detailed measurement of hydraulic and bathymetric data through the study reach. Bed-material samples will be collected at all sites. All data will be used for the physical and mathematical components of the project.

LITERATURE CITED

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